UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 5

MEMORANDUM

DATE: May 1, 1998

SUBJECT: Response to National Remedy Review Board Recommendations on the Continental Steel Superfund Site, Kokomo, Indiana

FROM: William E. Muno, Director
Superfund Division

Wm. E. Muno

TO: Bruce Means, Chair
National Remedy Review Board

The purpose of this memorandum is to provide a response to the May 14, 1997 memorandum issued to Region 5 regarding the National Remedy Review Board (NRRB) recommendations on the Continental Steel Superfund Site located in Kokomo, Indiana. Region 5 has worked closely with the Indiana Department of Environmental Management (IDEM) on addressing the recommendations received from the NRRB. As you may be aware, IDEM is the designated lead agency for this site.

I have given careful consideration to the NRRB's recommendations in addition to the detailed response provided for each recommendation by IDEM. In conclusion, I concur with the responses provided by IDEM in the attached documents.

Overall, Region 5 and IDEM agree that a number of the recommendations should be incorporated into the final proposed remedy for the site. The following highlights the most significant changes incorporated:

- Active identification and utilization of alternative fill materials for backfilling the Markland Avenue Quarry;

- Elimination of the shallow groundwater extraction wells further down gradient of the Markland Avenue Quarry;

- Installation of a shallow groundwater extraction system directly down gradient of the Markland Avenue Quarry; and

- Utilization of soil covers at the Markland Avenue Quarry, Main Plant Area and Slag Processing Area.

The estimated cost savings resulting from these changes is approximately $ 6.9 million. A review of the responses will also reveal that several of the other NRRB recommendations have also been incorporated into the final proposed site remedy. Although these changes enhanced the overall remedy selection process for the site, no additional cost savings are associated with these changes.

In addition to the direct benefit of the NRRB review on the proposed remedy, one of the recommendations from the NRRB has been incorporated into the implementation of two other site activities - an Interim Record of Decision (IROD) and a Non-Time Critical Removal Action (NTCRA). Under the IROD, decontamination and demolition of buildings on the Main Plant Area will occur. An Action Memo for a NTCRA to address lead contaminated soils in residential yards adjacent to the site has also been signed. For both of these actions, Region 5 and IDEM had anticipated disposing of building demolition/debris and lead contaminated soils off-site at a commercial disposal facility. After giving careful consideration to the NRRB recommendation regarding the use of alternative fill for backfilling the Markland Avenue Quarry, Region 5 and IDEM will attempt to stockpile suitable materials from these actions to be used as fill at the site. If Region 5 and IDEM are able to define some materials as "suitable fill material", additional cost savings will be realized for the IROD and NTCRA as well.

If you have any questions regarding this response or the attachment, please contact Wendy Carney, Region 5's representative to the NRRB.

Attachment

INDIANA DEPARTMENT OF ENVIRONMENTAL MANAGEMENT

We make Indiana a cleaner, healthier place to live

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Governor

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October 22, 1997

Ms. Wendy Carney, HSRM-6J
U.S. Environmental Protection Agency
77 West Jackson Boulevard
Chicago, IL 60601

Ms. Carney:

Re: Response to NRRB Recommendations and EPA Comments

On September 15, 1997, the Indiana Department of Environmental Management (IDEM) received additional comments via electronic mail (e-mail) from the U.S. Environmental Protection Agency (EPA) concerning the IDEM Responses to the Recommendations from the National Remedy Review Board (NRRB). IDEM compiled specific, focused responses to these comments and sent them via facsimile to EPA on the morning of October 16, 1997. At your suggestion and per IDEM request, EPA and IDEM conducted a conference call to discuss the responses in the facsimile later that afternoon.

Based on the discussions from the conference call, IDEM has revised and edited these responses. The EPA comments along with the IDEM revised responses are as follows:

Comment: At this point, EPA is not certain it makes sense to remove the sediments from Markland Avenue Quarry. EPA rationale is that we are leaving a fairly significant volume of similarly contaminated material contained within the quarry and have been able to define containment as being sufficiently protective.

- Sediment samples collected from the Quarry for Solidification/Stabilization Treatability Studies at the EPA S.T.A.R.T. Research Laboratory in Cincinnati, Ohio indicate high concentrations of TCE.
  - TCE in these samples is 220,000 ppb, with a TCLP of 3,000 ppb and a SPLP 3,400 ppb. (See attachment for results.)
  - This data confirms earlier samples collected by EPA contractors (TCE of 230,000 ppb) performing an emergency removal action on drums discovered in the Quarry. (Data is available from EPA Emergency Response staff upon request.)
- During backfilling operations, resuspension of contaminated sediments and free phased DNAPL would most likely occur. There is a high possibility the resuspended contaminants would enter/affect the shallow groundwater aquifer

(CDM has recently experienced this event at a TRW site in Ohio.), which would compromise containment of the contaminants. Since the proposed pumping system (in close proximity to the quarry) was designed to contain migration of low level quarry contaminants only within the shallow aquifer, resuspending free phased DNAPL and elevating the contaminant levels in the shallow aquifer would alter the containment Scope of Work. The current arrangement for the pumped containment water is for NO COST disposal through the City of Kokomo POTW. This arrangement is provided the groundwater contaminant levels are low and free-phased DNAPL is not present. Therefore, alteration to the pumping system will likely be required to maintain this arrangement. This would require additional costs than originally projected in the FS for the site-wide and Quarry groundwater treatment/containment proposed alternative. The additional costs would include, but not be limited to, upgraded pumping equipment, pretreatment system, and extended O&M, which could potentially be burdensome on the State. However, EPA is responsible for 100% of the cost associated with the first year O&M, which would possibly be the greatest impact for DNAPL recovery. Unfortunately, this variable cannot be adequately projected at this time. On the other hand, removing the source of the DNAPL is feasible and has been projected in the proposed alternatives of the FS and the recommendation to the NRRB.

- The proposed Alternative for the Quarry includes approximately $4.7M in off-site disposal costs. Taking the Quarry sediments to the CAMU for disposal would cost approximately $1.7M. This would amount to nearly $3.0M in savings from the proposed alternative for the Quarry and would eliminate the possibility for groundwater treatment system changes that could easily approach if not exceed the Quarry sediments disposal in the CAMU option.

Comment: The quarry sediment was a fair volume of material. If not removed, EPA needs to know that the option of off-site disposing the remainder of the materials and surcharging the lagoons has been explored.

- The Quarry sediments make up approximately 28,000 cubic yards (dewatered) of the total 206,000 cubic yards of material slated for disposal in the CAMU and determined as cost effective and most protective of human health and the environment in the FS. This volume amounts to 12.5% of the total volume and 3.8% ($1.7M) of the total cost ($44.7M) for the selected Lagoon Area proposed remedy.
- As shown in the tables below, the CAMU is the most cost effective means of handling the contaminated materials determined in the FS as necessary for excavation and containment/disposal in order to prevent exposure to the environment and humans and requiring some form of adequate containment.

Lagoon Area Costs Including Quarry Sediments

Option Description	Volume (cu. yds.)	Unit Cost (per cu. yd.)	CAMU Contents Total Cost	Lagoon Area RCRA Closure(*)	Total Cost Lagoon Area
CAMU	206,000	$60.00	$12,360,000	$13,700,000	**$26,060,000**
Off-site Disposal (✓)	206,000	$175.00	$36,050,000	$5,000,000	**$41,050,000**

Lagoon Area Costs Excluding Quarry Sediments

Option Description	Volume (cu. yds.)	Unit Cost (per cu. yd.)	CAMU Contents Total Cost	Lagoon Area RCRA Closure(*)	Total Cost Lagoon Area
CAMU	178,000	$60.00	$10,680,000	$13,700,000	**$24,380,000**
Off-site Disposal (✓)	178,000	$175.00	$31,150,000	$5,000,000	**$36,150,000**

(*) RCRA Closure does not include the cost that would be necessary for proper RCRA Closure that would be applicable to both Options (CAMU & Off-site Disposal). Off-site Disposal option utilizes surcharging for RCRA Closure.

(✓) Off-site Disposal option is based on the average disposal cost from three Subtitle D facilities. Transportation is included in the cost.

The numbers have been updated to reflect a more accurate representation of the quantities and costs associated with the areas of concern. The original numbers were determined by rounding numbers up (These numbers/figures were in the NRRB presentation presented in San Francisco.).

- **Updated Contaminated Material Numbers:** (CAMU content quantities)
  - **95,000 cubic yards** of highly contaminated materials (associated with the Lagoon Area but not in the CAMU designated area; elevated VOC, SVOCS, & Metals locations)
  - **34,000 cubic yards** of PCB & metals contaminated soils from creek bank adjacent to the Main Plant and elevated VOC areas on Main Plant
  - 61,000/**51,000 cubic yards** from creek sediments (sediments removed/dewatered sediments)
  - 35,000/**28,000 cubic yards** from the Quarry sediments (sediments removed/dewatered sediments)

- The CAMU will also greatly benefit the other OUs in NET cost structure/savings and protectiveness to the environment and human health.
- The direct cost benefit of surcharging would be a savings of $8.7M. Then, to adequately and appropriately handle the hazardous wastes from all the OUs would require off-site disposal at a cost differential of $23.7M. The NET result of changing to surcharging the lagoon wastes and disposing of the other wastes off-site would be a **net increase** of **$15M** over implementation of the CAMU option. Furthermore, after discussing the surcharging of the lagoon wastes with IDEM-

RCRA, they felt that the surcharging option for the lagoon wastes would be less protective (it does not minimize the Toxicity or Leachability of the hazardous waste) than the alternative proposed to the NRRB.

Comment: EPA also had concerns regarding the type and cost of the proposed material used to backfill the Markland Avenue Quarry.

- IDEM anticipates utilizing and will endeavor to utilize various other materials to backfill the quarry such as construction debris from local contractors. However, due to the implementability evaluation criteria, IDEM projected the type and cost of backfill materials based on readily available materials that carry a cost. Any savings or reliance on these materials would be difficult to determine or estimate without knowing the market for these items.

You will also find enclosed a copy of the Final Response to the National Remedy Review Board Recommendation. During our conference call, there was discussion concerning IDEM conducting a Focused Briefing for Mr. Muno. Please inform us of your decision. If you have any questions concerning this letter or the enclosures, or would like to establish a meeting time with Mr. Muno and yourself, call me at AC 317/308-3115 or e-mail me at kherr@opn.idem.state.us.

Sincerely,

Kevin D. Herron

Kevin D. Herron, Project Manager
Superfund Section
Continental Steel Site
Office of Environmental Response

KDH:mg
enclosures
cc: Jon Peterson, U.S. EPA
Mark Burgess, Camp Dresser & McKee

Superfund Technical Assistance Response Team

START PROGRAM
SPECIAL INVESTIGATION

Solidification/Stabilization Bench-Scale Treatability Studies
Performed on Acid and Non-Acid Sludges from the
Continental Steel Superfund Site
Kokomo, Indiana

FINAL REPORT

July 17, 1996

Prepared by:
Science Applications International Corporation
635 West Seventh Street, Suite 403
Cincinnati, Ohio 45203

Prepared for:
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U.S. EPA, NRMRL
and
John O'Grady, Regional Project Manager
U.S. EPA, Region V

EPA Contract Number 68-C5-0001
Work Assignment 1-04, TD F
SAIC Project No. 01-0832-07-6404-x09

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Douglas Grosse
National Risk Management Research Laboratory
Office of Research and Development
U.S. Environmental Protection Agency
Cincinnati, Ohio 45268

Table B-1. Quarry Sediment Analytical Results for VOCs

Compound	TWA[b]	SPLP[c]	TCLP[d]	TCLP Limit[e]	MCL[f]
Benzene[a]	<42 [g]	<20	<20	500	5
Bromoform	<42	<20			
Carbon tetrachloride[a]	<42 [g]	<20	<20	500	5
Chlorobenzene[a]	<42	<20	<20	100,000	100
Chlorodibromomethane	<42	<20			
Chloroethane	<83	<40			
2-Chloroethylvinyl Ether	<420	<200			
Chloroform[a]	<42	<20	<20	6,000	100
Dichlorobromomethane	<42	<20			
1,1-Dichloroethane	<42	<20			
1,2-Dichloroethane[a]	<42 [g]	<20	<20	500	5
1,1-Dichloroethene[a]	<42 [g]	<20	<20	700	7
cis-1,2-Dichloroethene	<42	<20			70
trans-1,2-Dichloroethene	<42	<20			100
1,2-Dichloropropane	<42 [g]	<20			5
1,3-Dichloropropene	<42	<20			
Ethylbenzene	<42	<20			700
Methyl Bromide	<83	<40			
Methyl Chloride	<83	<40			
Methylene Chloride	<83	<40			
Methyl Ethyl Ketone	<1,700	<200	<200	200,000	
1,1,2,2-Tetrachloroethane	<42	<20			
Tetrachloroethene[a]	<42 [g]	<20	<20	700	5
Toluene	<42	<20			1,000
1,1,1-Trichloroethane	<42	<20			200
1,1,2-Trichloroethane[a]	<42 [g]	<20			5
Trichloroethene[a]	220,000	3,400	3,000	500	5
Trichlorofluoromethane	<42	<20			
Vinyl chloride[a]	<83 [h]	<40	<40	200	2

[a] Critical compound
[b] Results are in ug/kg dry weight.
[c] Results are in ug/L.
[d] Results are in ug/L.
[e] Limits are in ug/L.
[f] Limits are in ug/L.
[g] Reporting limit for TWA indicates maximum concentration in SPLP leachate cannot be in excess of MCL (due to 20 fold dilution resulting from SPLP).
[h] Reporting limit for TWA indicates maximum concentration in SPLP leachate could be in excess of MCL.

Indiana Department of Environmental Management

Continental Steel Superfund Site Focused RI/FS

Response to National Remedy Review Board Recommendations

October 1997

Final
Project Number: 2673

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Appendix

1 Introduction

On April 22 and 23, 1997, the Indiana Department of Environmental Management (State) presented a briefing of the Continental Steel Superfund Site (CSSS) Remedial Investigation/ Feasibility Study (RI/FS) to the U.S. EPA National Remedy Review Board (NRRB) in San Francisco, California. In addition, the State presented its preferred alternatives for remediation of the site based on the RI/FS.

This report presents responses to the NRRB's recommendations dated May 14, 1997 which were generated in response to the State's presentation of its preferred alternatives. In general, many of the recommendations made by the NRRB were also contemplated/evaluated by the State's contractor, Camp Dresser & McKee Inc. (CDM), during preparation of the FS. In the interest of remedy cost savings, a number of the Board's recommendations should be given further consideration during the development of the Record of Decision and when the selected alternatives are more finely tuned during the Remedial Design (RD) phase. However, the State believes the alternatives and cost estimates presented in the FS are well within guidelines and adequate for site remedy selection.

Section 2 of this report presents the NRRB's recommendations and the State's responses. **Table 1-1** presents a summary of the cost impacts of the NRRB's recommendations evaluation upon the preferred alternatives selected by IDEM.

TABLE 1-1
Preferred Alternative Revisions Based on NRRB Recommendations
Continental Steel Superfund Site
Kokomo, Indiana

Operable Unit	Alternative	Previous P.W. Cost ($ M)	Revised P.W. Cost ($ M)	Revision
Lagoons	SC-4L	44.7	44.7	N.C.[a]
Creeks	SC-4C	12.6	12.6	N.C.[a]
Markland Quarry	SC-2.5Q	17.3	11.2[b]	Alternative Fill, Common Fill Barrier, On-Site Sediment Disposal, and Shallow Groundwater Extraction
Main Plant	SC-3.5M	8.0	7.7	Common Fill Barrier
Slag Processing Area	SC-3S	2.6	2.4	Common Fill Barrier
Site-Wide Groundwater	MM-5	6.4	6.1	Remove Shallow Groundwater Wells Downgradient of Quarry
Total		**$91.6M**	**$84.7M**	

a. N.C. = No Change
b In addition to NRRB recommendations, costs have been adjusted for on-site disposal of quarry sediments previously proposed for off-site disposal.

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2 Recommendations and Responses

This section presents recommendations from the NRRB for the Continental Steel Superfund Site and responses from the State. Recommendations and responses are presented in the same order and under the same subheadings used by the NRRB in its May 14, 1997 memorandum. The State received assistance from its contractor, CDM, in generating these responses.

2.1 General

1. Recommendation

The State should clearly explain the extent to which site wastes either do or do not constitute principal threat source materials as defined in the National Contingency Plan and related guidance. Where any site wastes are identified as principal threat materials, decision documents should explain how the remedy addresses the NCP's preference for treatment of these materials.

Response

The site contaminants of concern pose a potential risk above 10E-03 only in the creek sediments. All other source materials exhibit low toxicity and low mobility in the environment. The greatest excess risk of the creek's sediments is 8.0E-03, occurs in only one reach of the creeks and is almost entirely due to exposure to PCBs. The other contaminants are PAHs and metals. This risk is considered to be above acceptable risk range, and the wastes are relatively immobile. Therefore, the site is not considered to have any principal threat wastes.

The site contaminants are considered low level threat wastes that generally can be reliably contained and that present only a low risk in the event of release. The proposed remedial actions for the site comply with the NCP by providing "engineering controls, such as containment, for waste that poses a relatively low long-term threat." (Superfund Publication: 9380.3-06FS, November 1991).

2.2 Groundwater

2. Recommendation

The State should fully develop and incorporate in the site decision documents a justification for the proposed Technical Impractibility (TI) waiver as well as the vertical and horizontal extent of the TI zone.

Response

The State, through its contractor, has incorporated a fully developed justification for a TI Waiver as Section 6 and Appendix E of the site Feasibility Study Report. The TI Waiver was approved by the U.S. EPA Region V TI Waiver committed in a letter to IDEM dated July 24, 1997.

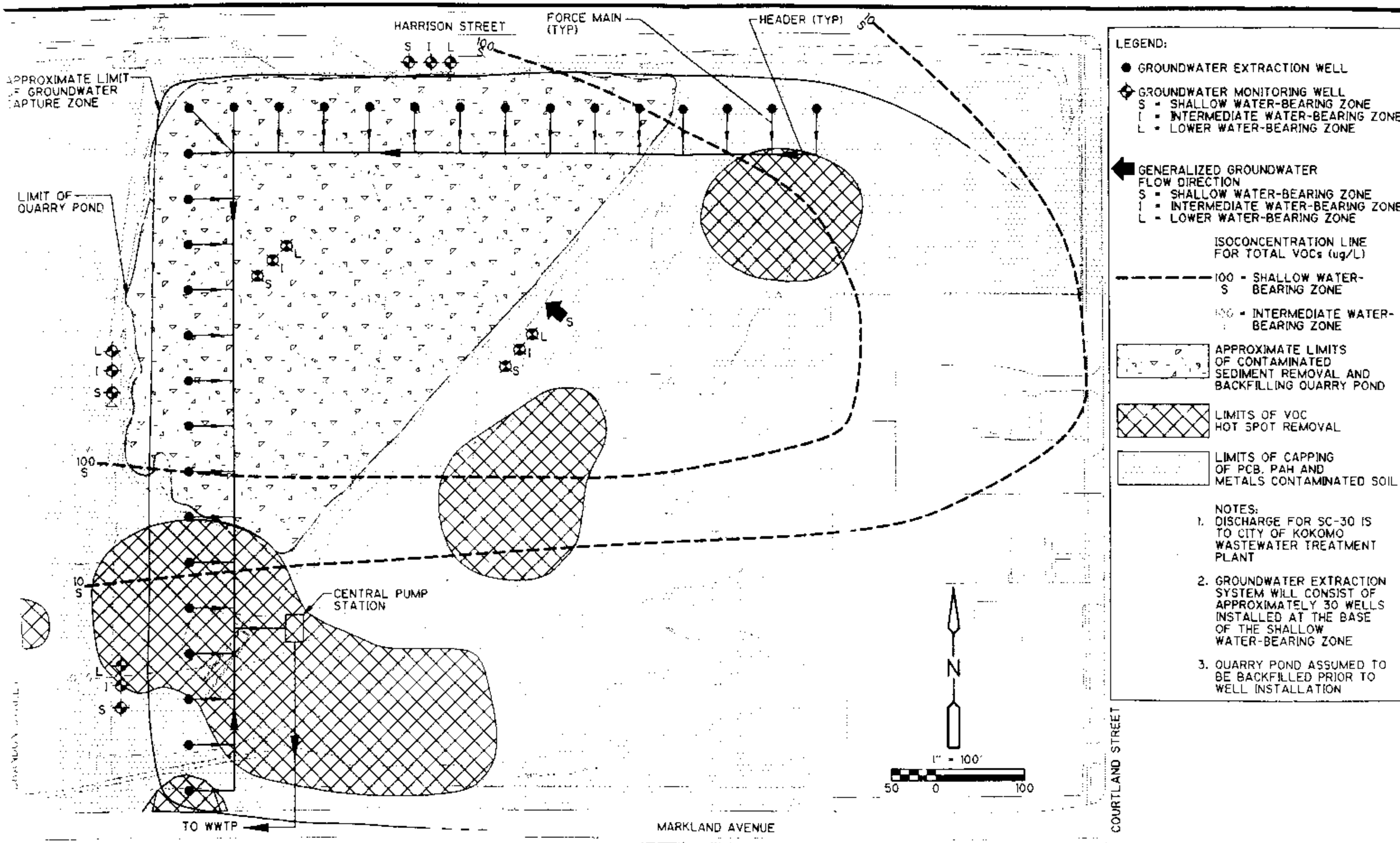
3. Recommendation

The State should evaluate the appropriateness of locating ground water extraction in the immediate vicinity of the [Markland Avenue] quarry in order to maximize control over potential plume migration westward toward the creek. For the area between the recovery system and the creek the State should investigate monitored natural attenuation as an alternative to the proposed recovery system to restore the shallow groundwater.

Response

Site-wide groundwater was defined as the intermediate and lower water-bearing zones throughout the CSSS and the shallow water-bearing zone that was present outside the limit of the source areas. As such, groundwater extraction alternatives in concert with natural attenuation were presented in the FS for the Markland Avenue Quarry as well as for site-wide groundwater.

For the Markland Avenue Quarry, alternative SC-3Q includes a system of extraction wells located along the western and northern perimeter of the quarry to intercept groundwater in the shallow water-bearing zone. This is shown in Figure 1. This line of extraction wells was situated immediately downgradient of the source area and can be considered in close proximity to the source area. In addition to the interception component, this system would also generate a capture area that should recover some contaminated groundwater in the shallow water-bearing zone that has already migrated from the source area. By inference, this alternative includes groundwater use restrictions and intrinsic remediation in the downgradient areas that were predicted to be affected by the migration of groundwater contamination that could not be recovered by the selected site-wide alternative. Alternative SC-3Q focused on the containment and collection of groundwater in the



CONTINENTAL STEEL SUPERFUND SITE
KOKOMO, INDIANA
FEASIBILITY STUDY

DM
...mental engineers, scientists, ... & management consultants

RESPONSE TO NATIONAL REMEDY REVIEW BOARD COMMENTS

SCHEMATIC LAYOUT FOR
MARKLAND AVENUE QUARRY
SOURCE CONTROL ALTERNATIVE SC-30

Figure 1

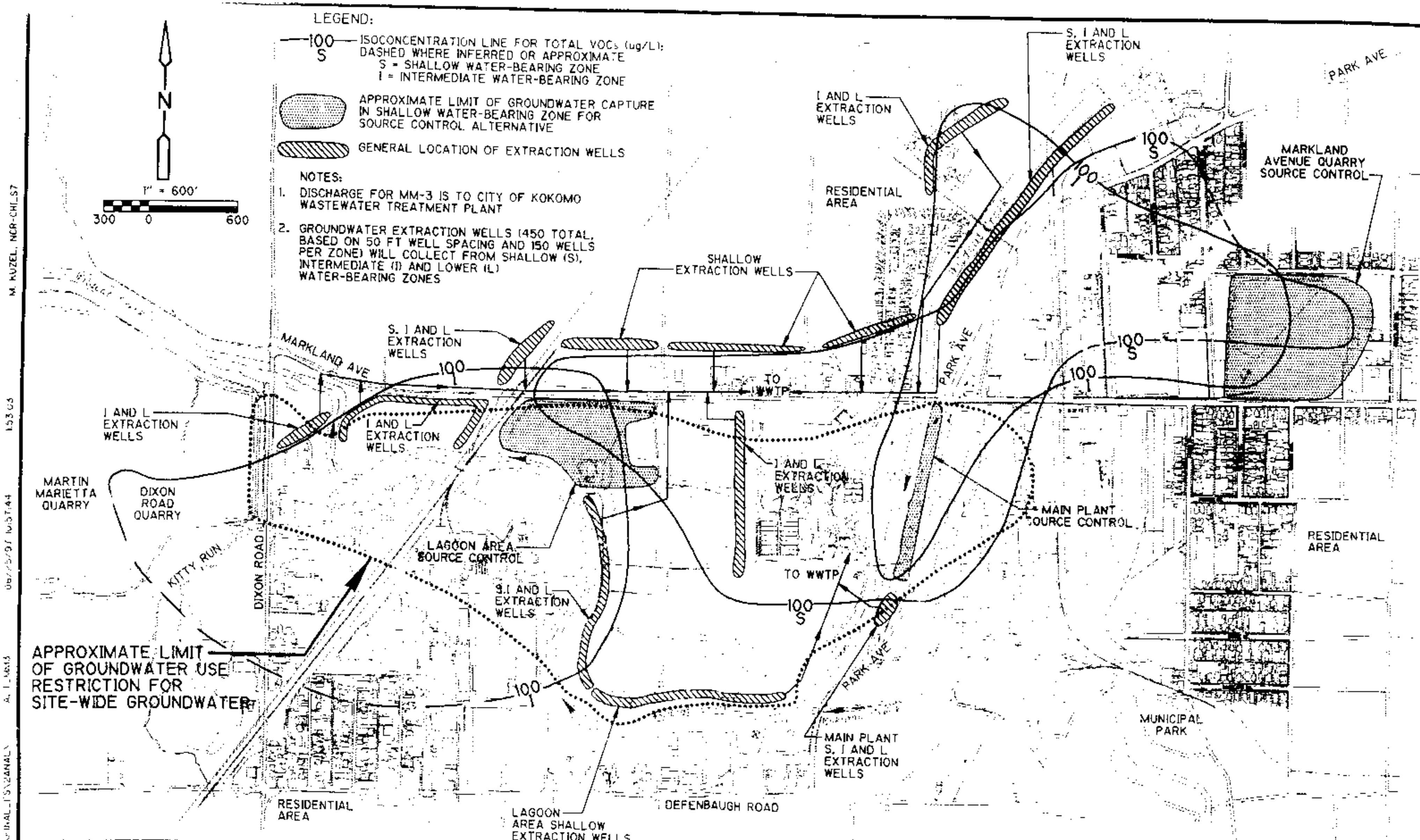
shallow water-bearing zone since the highly fractured nature of bedrock in this zone would be amenable to the effective collection of contaminated groundwater.

In order to provide a more aggressive means of groundwater collection and containment at the quarry source area, alternative SC-4Q was developed to include not only the western and northern perimeter wells, but also an equal number of wells situated within the quarry area itself. The purpose of these interior wells was to provide for the recovery of groundwater in immediate proximity to the source and to attempt to reduce the downward migration of contaminated groundwater and DNAPL to the intermediate and lower water-bearing zones. It was discussed that this interior collection system would be only marginally effective, since it is very difficult to generate a capture zone in less fractured bedrock that may not have continuous hydrogeologic properties. In addition, since DNAPL sources would follow paths of least resistance through the bedrock fractures, the likelihood that DNAPL pockets would be intersected by the wells would be very low. The use of intrinsic remediation in the shallow water-bearing zone beyond the capture zone was similar to that for alternative SC-3Q.

These two alternatives provided for the containment and/or collection of contaminated groundwater and DNAPL within the Markland Avenue Quarry source area. These alternatives resulted in the assumption that no further contamination would migrate downward from the shallow water-bearing zone. The assumption is also made that contaminated groundwater outside of the capture zone will intrinsically remediate within a period of approximately 20 years.

In addition to the source control alternatives, the management of migration alternatives for site-wide groundwater also considered the use of groundwater extraction wells for alternatives MM-3, MM-4 and MM-5. Alternatives MM-3 and MM-4 utilize up to 450 groundwater extraction wells within the shallow, intermediate and lower water-bearing zones to collect and/or contain groundwater with contamination above ARARs. Alternative MM-5 utilizes groundwater extraction wells in the shallow water-bearing zone and relies on continued pumping at the Martin Marietta Quarry as the means to contain groundwater contaminated above ARARs in the intermediate and lower water-bearing zones. These alternatives do rely by inference on intrinsic remediation as a means to reduce groundwater concentrations over time.

It is noted that the groundwater extraction wells are shown schematically as a line of wells in several areas of site-wide groundwater as shown on Figures 2 and 3. It was suggested by the NRRB that in lieu of the line of shallow groundwater extraction wells shown schematically downgradient from the Markland Avenue Quarry, that a line of wells be installed immediately downgradient of the quarry (much as for the source control alternatives presented in the FS) and natural attenuation be utilized for the groundwater downgradient of the capture zone.



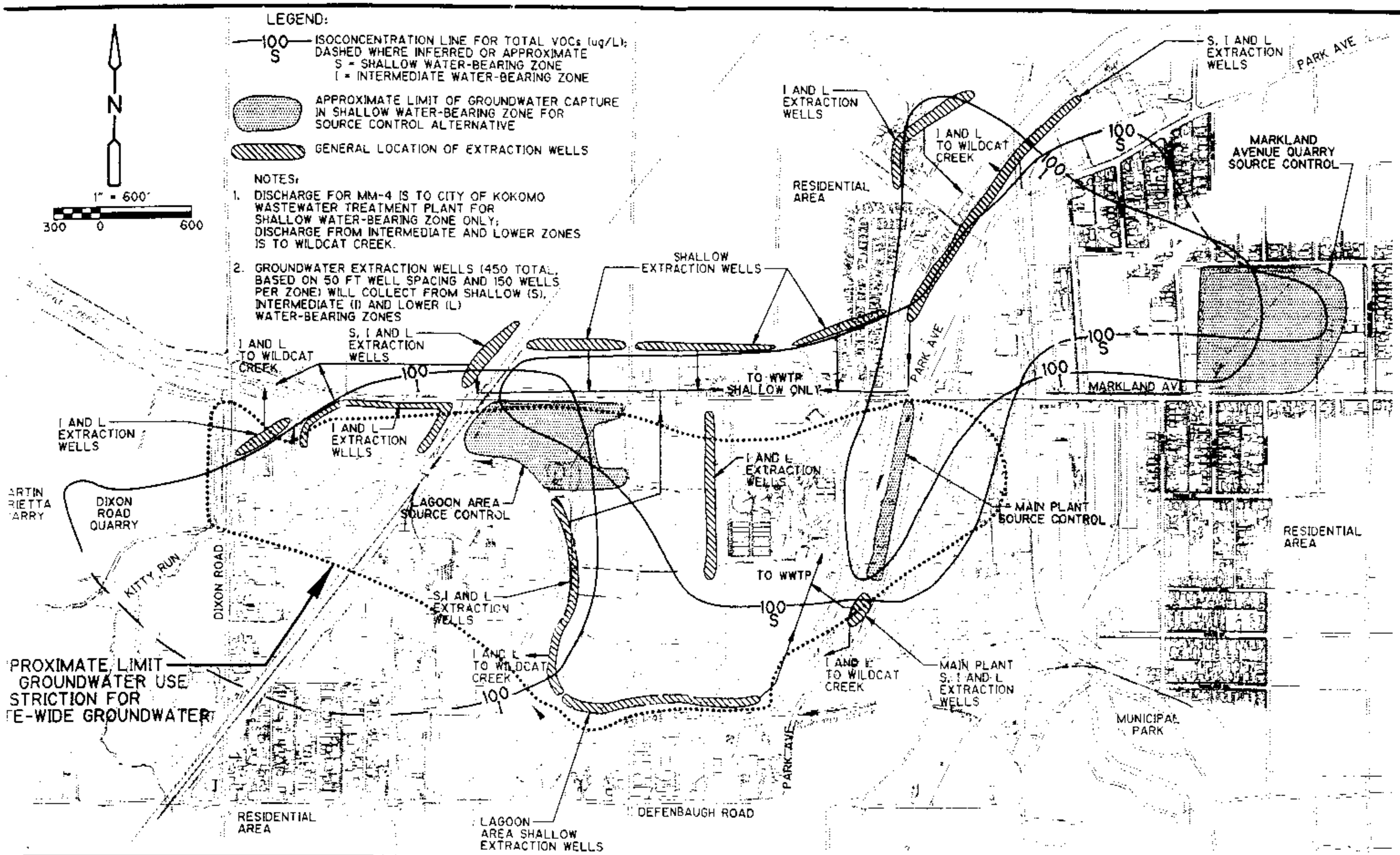
CONTINENTAL STEEL SUPERFUND SITE
KOKOMO, INDIANA
FEASIBILITY STUDY

RESPONSE TO NATIONAL REMEDY REVIEW BOARD COMMENTS

CDM
environmental engineers, scientists, planners, & management consultants

SCHEMATIC LAYOUT FOR SITE-WIDE GROUNDWATER ALTERNATIVE MM-3

Figure 2



CONTINENTAL STEEL SUPERFUND SITE
KOKOMO, INDIANA
FEASIBILITY STUDY

RESPONSE TO NATIONAL REMEDY REVIEW BOARD COMMENTS

DM
...ental engineers, scientists, ... management consultants

SCHEMATIC LAYOUT FOR SITE-WIDE GROUNDWATER ALTERNATIVE MM-4

Figure 3

This proposed alternative by the NRRB could be utilized for the quarry. The State, in selecting its preferred alternative, did not believe it cost-effective to provide shallow groundwater controls for contaminants released from the quarry both at the source and downgradient for site-wide groundwater. The State selected the site-wide control as its preferred alternative based on cost and its desire to minimize the need for groundwater use restrictions outside of the present extent of groundwater contamination. Of primary importance was the desire to not allow groundwater contamination above ARARs to potentially migrate to the northwest toward residential areas heretofore unaffected by groundwater contamination. Therefore, the decision was made to intercept the leading edge of the plume in the vicinity of the quarry. In addition, selection of the site-wide shallow groundwater control alternative in this vicinity results in a cost savings of approximately $50,000 compared to the quarry source control alternative (SC-3Q).

It is estimated that the downgradient extraction combined with intrinsic remediation of the upgradient shallow groundwater will attain ARARs in approximately 30 years. This estimate is 10 years longer than that expected with extraction at the quarry. However, the State believed the extra remediation time was reasonable, given the cost savings and other considerations discussed above.

Upon further review, the State concurs with the NRRB's recommendation because it should achieve ARARs in shorter timeframe in this vicinity and is more compatible with guidance given for justification of the groundwater TI waiver (i.e., implementation of source controls to the extent practical). The State agrees that shallow groundwater control as described in SC-3Q in lieu of adjacent to the creek as described in MM-5 is desirable, even though it will add approximately $50,000 to the suggested remedy for the site as a whole. This increase in cost of the site-wide remedy is reflected by an increase in the estimated cost of the preferred alternative for Markland Avenue Quarry (2.5Q) of $390,000 and a decrease in the estimated cost of the preferred alternative for site-wide groundwater (MM-5) of $340,000.

4. Recommendation

To the extent the State considers monitored natural attenuation as a means for ground water remediation (either as part of the proposed or alternative actions), it should evaluate this remediation approach using site-specific characterization data and analyses that considers such factors as:

- Historical ground water and/or soil chemistry data that demonstrates a clear and statistically meaningful trend of declining contaminant mass and/or concentrations at appropriate monitoring or sampling points;

- Site characterization data that can be used to indirectly demonstrate the type of natural attenuation processes active at the site, and the rate at which such processes will reduce contaminant concentrations to required levels; for example, data needed for demonstrating occurrence of biological degradation processes include levels of dissolved oxygen, nitrite, iron (II), sulfate, methane, and carbon dioxide, among others; and

- Data from field or microcosm studies (conducted in or with actual contaminated site media) that directly demonstrate microbial activity in the soil or aquifer material and its ability to degrade the contaminant of concern.

Response

Groundwater and soil chemistry results are generally limited to two rounds of sampling (1993 and 1995). A qualitative evaluation of the available data indicates that in source areas and associated contaminant plumes, the concentrations of parent products has generally decreased and daughter or breakdown products has increased over a period of two years between sampling events. Likewise, a similar relationship is seen with depth. As an example, the ratio of parent (TCE) to daughter (cis- and trans-1,2-DCE, 1,1-DCE, and vinyl chloride) constituents decreases in the intermediate and lower water-bearing zones between 1993 and 1995 (see Table 2-1). This relationship is also seen with increasing depth as would be expected if anaerobic biodegradation were occurring. The strength of this relationship is even greater if constituent densities are considered - TCE is significantly denser than cis- and trans-1,2-DCE, 1,1-DCE and vinyl chloride which would tend to increase the parent/daughter ratios with depth if density gradients were dominating migration.

Aerially, constituent concentrations generally decrease with distance from the source and daughter compounds become more prevalent (parent to daughter ratios generally less than one vs. greater than two near source areas). These trends, although qualitative, are strong indicators that anaerobic degradation of the chlorinated compounds is occurring especially at intermediate and lower water-bearing zone intervals.

The majority of the analytes indicated for evaluation of biodegradation processes are not available for use in evaluating degradation rates. However, the ratios discussed above are an indication that degradation of the parent compounds is occurring. Based on the limited data evaluated, CDM believes the rates of reduction implied (20 to 30 percent per year) should only be viewed as evidence of degradation with no conclusions drawn regarding the actual expected rates for selection of remedial alternatives. Monitoring of analytes and compounds for evaluating biodegradation processes during the first years of remediation activities will confirm that these processes are occurring concurrent with other remediation activities planned at the site and that natural attenuation is compatible with the proposed remedies for the site.

TABLE 2-1
Ratio of Parent to Daughter
Constituents at Well LA-04
Continental Steel Superfund Site
Kokomo, Indiana

Water-Bearing Zone	Depth	1993	1995
Intermediate	45		2.15 (2.54)
	50	4.08	
	60		.23 (.28)
	65	.70	
Lower	111		4.83×10^{-3}
	131	1.92 (1.75)	

Note: Parent = TCE concentration
Daughter = Sum of cis- and trans-1,2-DCE, 1,1-DCE and vinyl chloride concentrations
( ) = Duplicate sample

No field or microcosm studies were conducted specifically at this site. Based on conventional parameters, there are no indications that organisms typically found in groundwater should not be present in site-wide groundwater. There were some high pH conditions in several source areas but not in site-wide groundwater. Therefore, based on discussions above, it is our position that natural attenuation is a reasonable technology to apply to this site.

The effectiveness of natural attenuation will be measured over time through groundwater monitoring of selected wells. The current program for groundwater sampling includes 5 shallow groundwater wells for the Lagoon Area; 5 shallow wells for Markland Avenue Quarry; 2 shallow and 6 intermediate and deep wells at the Main Plant; and 10 nests, each consisting of a shallow intermediate and deep monitoring well, for site-wide groundwater. The costs of well installation were included in the detail cost tables provided in the Final FS Report.

Groundwater sampling has been included in the remediation cost estimate for the source areas and site-wide groundwater. This sampling would be performed

quarterly for the first two years, semi-annually for the next two years, and annually thereafter for up to 30 years for the source areas and 200 years for site-wide groundwater. The primary constituents to be sampled included organic and inorganic analyses, as appropriate for the source area and site-wide groundwater. Occasional analyses will be included for degradation indicators, including electron acceptors, metabolic byproducts, field parameters and nutrients in groundwater. Costs for these analyses have been included within the cost tables presented in the FS.

Therefore, the monitoring program for natural attenuation, as outline above, has been adequately budgeted in the Final FS cost tables.

2.3 Markland Avenue Quarry

5. Recommendation

The state proposed to leave existing contaminated fill material in the Markland Avenue Quarry in view of this fact.

- The State should fully develop and explain in its decision document of this site the rationale for removing the sediments and sludge from the quarry;
- The Board is concerned that the quarry may remain a long-term source of contamination to the shallow ground water. The State should evaluate the appropriateness of ground water extraction in the immediate vicinity of the quarry in order to minimize control of potential for plume migration; and
- In view of the possibility that the quarry fill may remain a long-term contamination source. The State should consider using quarry fill materials that are more cost effective than "clean" fill to the extent allowable under state and federal law (e.g., building debris).

Response

The cost to excavate 35,000 cubic yards of quarry sediment is approximately $900,000 compared to more than $30 million to excavate up to 1.28 million cubic yards of contaminated fill. After excavation, the State proposed gravity dewatering of the sediments to an approximate volume of 28,000 cubic yards prior to disposal. Off-site disposal of the dewatered sediments at a Subtitle D facility is estimated to cost approximately $4.8 million compared to approximately $1.7 million for disposal in the on-site CAMU.

The State's list of preferred alternatives includes approximately 206,000 cubic yards of contaminated materials which are proposed to be disposed in the on-site CAMU. If the sediments are not removed from the quarry, there will still be approximately 178,000 cubic yards of contaminated materials to be disposed on-site or off-site. The approximate volumes of contaminated materials requiring disposal from each of the other source areas (i.e., excluding the quarry) under the State's preferred alternatives are as follows:

Lagoons (outside RCRA impoundments)	93,000 yd^3
Creeks (dewatered sediments)	51,000 yd^3
Main Plant	34,000 yd^3

Off-site disposal of this material at a Subtitle D facility would add an estimated $20 million to the State's preferred option of on-site disposal in a CAMU.

Analytical results for Trichloroethene in the quarry sediments were obtained by the U.S. EPA Superfund Technical Assistance Response Team (START) for the purpose of evaluating treatability. These results were as follows:

	TWA	SPLP	TCLP	TCLP Limit
Trichloroethylene:	220,000 µg/kg	3,400 µg/L	3,000 µg/L	500 µg/L

The sediment within the quarry pond is a known source of DNAPL based upon field observations. This DNAPL was assumed to have also migrated to the intermediate and lower water-bearing zones consisting of less fractured bedrock. However, it is suspected that a fairly significant portion of DNAPL (13 percent assumed) is contained within the sediment. Though the less fractured bedrock will continue to be a source for site-wide groundwater of dissolved DNAPL, removing the sediment and its associated DNAPL would impact the long-term degradation of the groundwater. The results of the groundwater model indicated that although times to attain ARARs would likely be governed by DNAPL in the less fractured bedrock (the impracticability of recovery served as the basis of the TI waiver), removal of the sediment would serve to improve groundwater quality and thus the time to attain ARARs, at least within the vicinity of source area itself. Furthermore, guidance provided by U.S. EPA for the TI waiver indicates that known sources must be controlled to the extent practical. It should also be noted that backfilling the quarry without removal of the sediments, combined with source area groundwater extraction in close proximity to the quarry (as agreed in the response to Recommendation 3), may mobilize the DNAPL. The result could be higher levels of contamination in the shallow groundwater and higher VOC concentrations in the recovered groundwater which may preclude direct discharge to the Kokomo WWTP.

As indicated in the response to Recommendation 3, the State has reconsidered its position on the issue of shallow groundwater control in the vicinity of Markland Avenue Quarry and now concurs with the Board. To provide a measure of protection against long-term groundwater degradation in the area, the proposed quarry source control alternative will include shallow groundwater extraction wells along the downgradient western and northern perimeter of the quarry. These wells will provide additional means to collect potential leachate from the contaminated fill left in place. It is noted that the cost to install and operate these extraction wells, even if for a prolonged duration, is significantly less than the remediation costs to excavate and dispose of the large quantity of contaminated fill material. With these wells in place, groundwater monitoring will be completed to assess when operation of these extraction wells could be terminated.

It is acknowledged and agreed that the quarry pond could be backfilled with material that would not be considered "clean" off-site borrow. It is possible that there would not be any cost for the materials themselves. However, it is very possible that there would be a cost of up to $1 million to transport approximately 350,000 cubic yards of this material (on-site or off-site) to the quarry pond. Use of alternative materials would result in considerable savings since the estimated cost for clean fill for the quarry was on the order of $4 million. The FS report discussed the potential use of main plant demolition material, assuming that it was sufficiently decontaminated, or material excavated from other source areas that was marginally contaminated or contaminated with constituents that were not readily mobile in groundwater. Use of alternative materials for filling the quarry will likely result in a prolonged time frame for implementation of the remedy since sufficient material may not be readily available.

6. Recommendation

It is unclear whether the added cost of the proposed impermeable cover designed to mitigate infiltration in the quarry area would be justified given that a significant amount of the quarry waste material would remain in the saturated zone. The State should consider a soil cover that is sufficient to prevent surface soil exposure (rather than one designed to mitigate infiltration). Such a cover may be constructed of relatively permeable and locally available soils.

Response

The State agrees with this comment. There is approximately 10 feet of unsaturated fill material within the quarry as compared to approximately 50 feet below the water table. The use of a low permeability cover could be eliminated in favor of a permeable soil cover, though infiltration of stormwater through this unsaturated fill could transport some constituents over time. A two foot barrier of soil could be

provided to prevent direct contact with the fill material. The State recommends that a low-cost warning barrier such as fluorescent orange litter or snow fencing material be installed at one foot depth to serve as a warning/caution for any future excavation of the potentially contaminated fill. This alternative would reduce the cost of the cover by approximately $300,000.

7. Recommendation

In the quarry area, the State appears to be proposing remediation goals based on direct residential use of quarry fill materials although future residential use of the quarry is not expected. The State should ensure that remediation goals and cap design are consistent with the expected future land use and its surrounding properties.

Response

The Markland Avenue Quarry is currently zoned for general use which allows for residential use. It is also bordered on three sides by existing residential areas/houses. These homes are directly adjacent to or abut the Markland Avenue Quarry property. While houses would not be expected to built on the quarry fill in the future, it is anticipated that residential use of the land directly adjacent to the quarry will continue. In addition, recreational use of the quarry (including the potential for a developed recreational use such as a park) is expected. Given the close proximity of homes to the quarry and the anticipated uses of the quarry, the State continues to believe that it is appropriate to establish residential remediation goals.

2.4 Kokomo and Wildcat Creeks

8. Recommendation

Regarding the proposed actions for the creeks, the Board recommends that cleanup levels at this site be no lower than background levels. This is because these creeks are located in heavily industrialized areas where any discrete cleanup to levels lower than "background" on-site would soon be overcome by the influence of sediments from numerous off-site upstream sources of these same contaminants.

Response

The State proposed "background" or risk based cleanup goals, if higher, for all contaminants except for PCBs. The cleanup goal for PCBs was set at 1 ppm due to ecological receptors and the Level V fish advisory already set for the creeks. However, the State agrees with the recommendation to set the creek cleanup goal

for PCBs at 5 ppm which is the "background" level. A review of the FS does not indicate any change in the alternatives or their costs based upon this increase in the PCB cleanup goal.

2.5 Lagoon Area

9. Recommendation

In evaluating the alternatives for action in the lagoon area against the NCP's "balancing criteria", the State should explain the value of the proposed excavation, making clear its relationship to flood storage capacity and stream bank maintenance.

Response

This recommendation actually has two issues. One is the need of the proposed excavation for flood storage capacity, and the other is the need for stream bank maintenance/excavation.

Whether the lagoons are capped in-place or they are consolidated to form the base of a cell to contain other on-site wastes, adequate protection of the sludges and cap must be provided against any high water events. Placing cap material or fill in the lagoon area floodway fringe (flood plain) would require compensatory flood storage to be constructed. The material in the floodway must be removed because there are no permanent protective measures that can be economically implemented. Excavating material in the floodway and along the floodway fringe would be considered to adequately satisfy the compensatory flood storage requirement. Of course, any cap system below the regulatory flood elevation of approximately 793 feet MSL would have to be armored or otherwise protected. The detailed plans for this would have to be completed during the Remedial Design process.

The stream bank soil is contaminated with low level VOC, PAH and PCB wastes. Again, there is no permanent protective measure that can be economically implemented in an area that is subject to high water events. The proposal is to excavate and remove the soils that contain contaminants in concentrations above the cleanup goals. The excavated soils would be contained in an on-site disposal unit, if built, or transported to an approved landfill off-site. The remaining stream bank would be graded and vegetated appropriately.

The proposed flood storage capacity and stream bank maintenance/excavation highly satisfy the "Balancing Criteria" of the" Long-term Effectiveness and Permanence" and "Reduction of Toxicity, Mobility or Volume." The proposed

actions are technically proven, protective, effective and implementable. This approach is compliant with ARARs, provides long-term effectiveness, reduces the mobility of contaminants, maximizes short-term effectiveness, and can be implemented using common construction methods.

10. Recommendation

The Board believes that there may be alternative (lower cost) approaches to constructing the proposed "Corrective Action Management Unit" in the lagoon area. For example, adequate dewatering and stabilization of the sludge may be achieved by surcharging the area to achieve load bearing capacity; while adequate cap performance may be achieved using the surcharge soils and proposed impermeable material. The Board recommends that the State evaluate the feasibility of this or similar approaches.

Response

The State agrees that lagoon sludge can be dewatered by surcharging the area to <u>improve</u> load bearing capacity. The State further agrees that if surcharge loading is selected, the material used for preloading can be utilized within the final cap design for the lagoons. The State would be in full agreement with the NRRB if the RCRA closure only of the lagoons were to occur in this area. However, the presence of the CAMU greatly affects the ability to surcharge the lagoon sludge and achieve a load bearing capacity adequate to support up to 40 feet of overlying contaminated fill material in the CAMU. In our opinion, the only way to achieve sufficient load bearing strength is through solidification or integrated construction sequencing that would require phased filling, extended construction durations, and added costs.

Generally, surcharging of sediment is performed to improve the load bearing capacity to support a capping system. It is often found more cost effective to surcharge the sediment rather than perform in-situ solidification. A recent discussion of this approach is outlined in the article "Containment System of an Industrial Wastewater Lagoon, including Surcharge Loading of Sediments for Cap Support" presented at the First International Congress on Environmental Geotechnics, Edmonton, Alberta, 1994. A copy of this article is included in Appendix A for reference.

The process for surcharging includes the installation of vertical drainage wicks to promote dewatering of the sediment/sludge, placement of a geofabric for material separation and to serve as a working mat, and placement of the surcharge material. This system can result in significant consolidation of the sludge as the water is removed by compression. Up to 50 percent reduction in sludge volume can be achieved, depending on initial water content and percent solids. The most cost-effective use of this design approach is for fairly thick deposits of sludge that will

have a typical capping system on the order of 5 feet in thickness. A key design issue is that the capping system is relatively small in load and uniformly spread out over the lagoon.

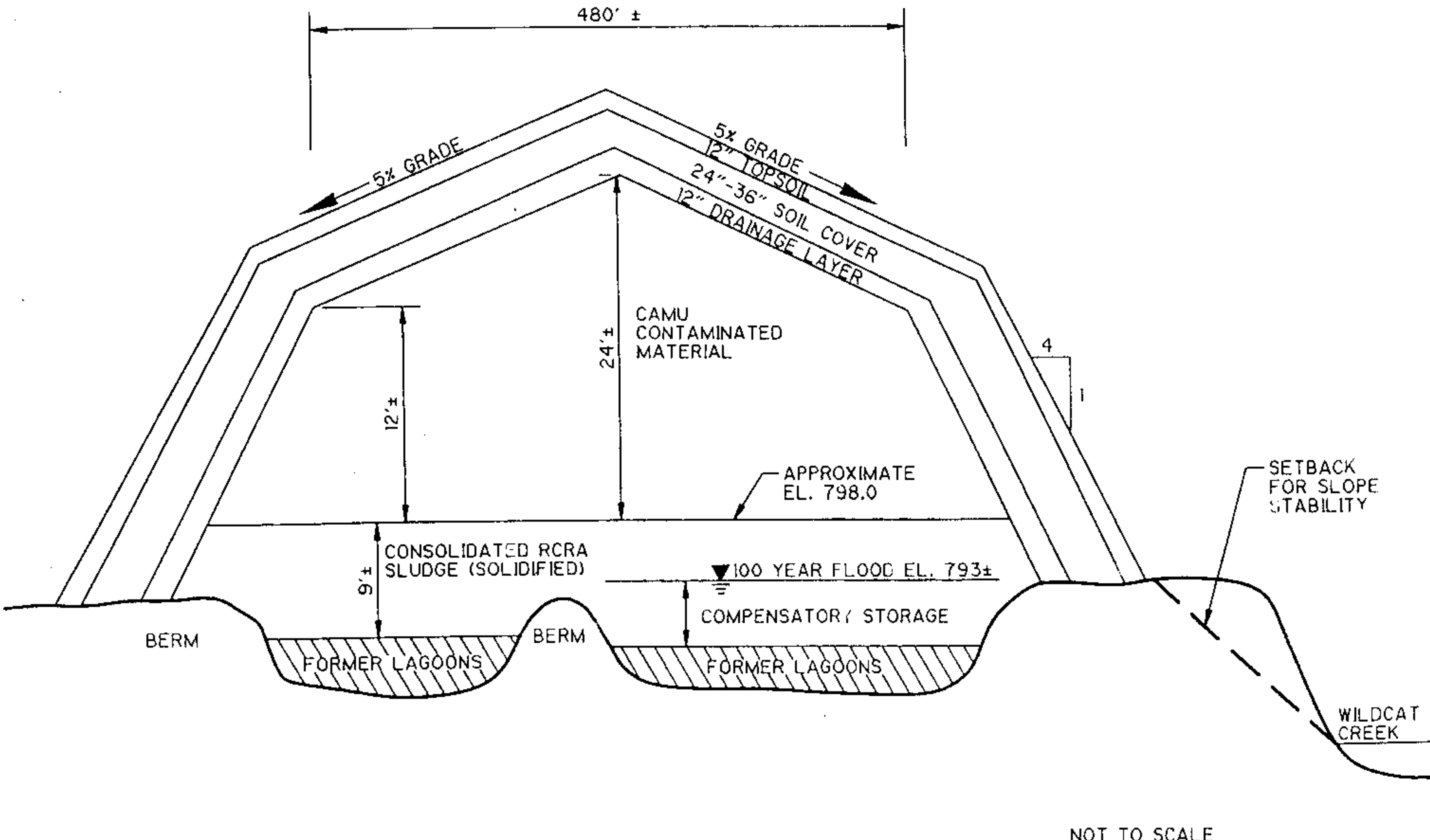
For this site, however, there are several site-specific issues that must be considered for design. A schematic cross section of the CAMU is presented as Figure 4. First, the location of the CAMU within a portion of the Lagoon Area results in up to 30 feet of fill material being situated above the lagoon sludge, with the height of fill varying across the site. CDM assessed the potential to situate the CAMU in other source areas. The Markland Avenue quarry area is not appropriate given the area is residential and the CAMU material contains mobile constituents that preclude its use to fill the quarry pond. The slag area is already elevated in topography and is not of sufficient area. The Main Plant is not applicable because of underground utilities and the potential for commercial development. The Lagoon Area was selected because it presents adequate area and is secluded from the public. Therefore, the lagoon closure must consider the CAMU presence or the materials proposed for disposal in the CAMU must be disposed off-site.

Surcharging lagoon sludge as subgrade for placement of an overlying capped landfill is generally not good engineering practice. This is even more important for this site since sludge from other lagoons must essentially be combined under the CAMU to provide compensatory flood storage. Design issues include slope stability, long-term secondary settlements, and overall foundation stability associated with bearing capacity. It is generally required that bearing strengths should be on the order of 25 to 50 psi to provide adequate long-term factors of safety. Surcharging will not be able to achieve this strength improvement, unless 25 to 50 feet of surcharge material is used. As a result, it is not likely that surcharging would be appropriate within the limit of the CAMU.

This conclusion results in two design options: 1) solidify the lagoon sludge to a compressive strength of 25 to 50 psi and locate the CAMU at the Lagoon Area; and 2) surcharge the lagoons, cap the lagoons in place, and dispose of the material previously designated for the CAMU off-site.

For the first option, the remedial cost to solidify the sludge was estimated at $13 million. The CAMU fill material was assumed to result in an on-site disposal cost of $60 per cubic yard to permit, construct, fill and cap the CAMU landfill. Therefore, the cost of this option, based on 206,000 cubic yards of CAMU material, is approximately $25 million.

For the second option, CDM has estimated that the cost to surcharge the lagoons would be on the order of $5 million in lieu of $13 million to solidify the sludge. The estimated cost of off-site disposal in a Subtitle D facility of up to 206,000 cubic



CONTINENTAL STEEL SUPERFUND SITE
KOKOMO, INDIANA
FEASIBILITY STUDY
RESPONSE TO NATIONAL REMEDY REVIEW BOARD COMMENTS

CONCEPTUAL CROSS-SECTIONAL VIEW OF CAMU LANDFILL

CDM
environmental engineers, scientists, planners, & management consultants

Figure 4

yards of material from the source areas is estimated at $36 million, using an estimated cost of $175 per cubic yard. Therefore, the total cost to surcharge sludge and dispose of other contaminated fill off-site may be in excess of $40 million. Though surcharging sludge is less costly than solidification, the site specific consideration of an on-site landfill results in higher overall remedial costs for surcharging sludge due to design considerations for the CAMU. The State continues to prefer solidification of the lagoon materials prior to placement of a CAMU in this area.

2.6 Main Plant and Slag Processing Areas

11. Recommendation

Based on the board's understanding that direct contact soil exposures present the only threats in the main plant and slag areas, the State should consider soil covers designed to prevent such exposures rather than the proposed impermeable caps designed to mitigate infiltration.

Response

The State agrees that direct contact soil exposure presents the only threats in the Main Plant and Slag Processing Areas. The use of a low-permeability soil cover was evaluated to provide a higher degree of protection for the groundwater. It was uncertain if buried drums could be present in the unsaturated zone. It was felt prudent to provide a higher degree of protection to groundwater for potential future releases from the fill by directing stormwater off-site.

Based upon further review, the State concurs that the low-permeability soil cover could be replaced by a permeable soil barrier though some continued migration of constituents in the unsaturated zone will likely occur over time. However, since a permeable soil barrier will not contain any distinctive subsurface layer (i.e., clay) that would indicate where contamination exists, the State recommends that a low-cost warning barrier (i.e., fluorescent orange litter or snow fencing material) be installed within the soil barrier to serve this purpose. This alternative would reduce the cost of the cover by $340,000 for the Main Plant and $250,000 for the Slag Processing Area.

Containment System of an Industrial Wastewater Lagoon, including Surcharge Loading of Sediments for Cap Support

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This paper presents a case study of the design and implementation of a containment system for sediments within a hazardous wastewater lagoon. The containment system consists of a soil/bentonite slurry wall keyed into an underlying glacial till strata, a groundwater extraction system to maintain an inward hydraulic gradient, and a geocomposite cap to reduce infiltration of precipitation. Significant cost savings were realized by controlling settlement of the cap through preconsolidation of the extremely soft sediments with a surcharge load rather than by in-situ solidification. This paper discusses the field and laboratory testing which was completed on the lagoon sediments, to model and monitor their behavior, as well as the difficulties experienced in placing and constructing the fill.

Background

The hazardous wastewater surface impoundment is part of a large industrial plant located in central Indiana, in the United States of America (USA). The impoundment had been in service since 1942 and occupies approximately 8 acres, consisting of two adjacent basins connected by a concrete spillway. The two basins functioned as a single integrated water retention, treatment, and solid particle removal unit. One basin was a concrete lined impoundment which was used for wastewater treatment. This basin measured about 350 feet by 70 feet. The second basin consisted of an unlined lagoon which was used as a wastewater retention and particulate settlement. This lagoon, measuring about 400 feet by 650 feet, had formerly been used as a sand and gravel borrow source, and therefore the sediments extended fairly deep. Figure 1 shows the general lagoon sediment thickness contours at the time it was removed from service.

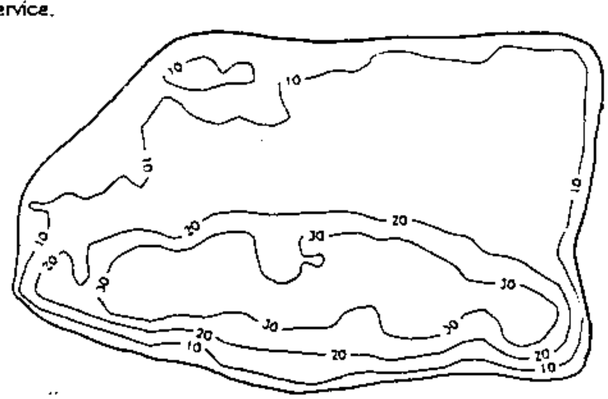

Figure 1 Lagoon sediment initial thickness contours (feet).

The surface impoundment received runoff from the plant's storm sewers, boiler blow-down water, ash quenching water from the power house, water softener rinse water, and non-contact cooling water. Prior to 1988 the impoundment also received effluent water from the plant's on-site wastewater treatment system.

The sludge and sediment that resulted from the wastewater treatment process was listed as RCRA F006 and F009 wastes. The USA Code of Federal Regulations, 40 CFR 261.31, defines these wastes as: "Wastewater treatment sludge from electroplating operations..." and "Spent stripping and cleaning bath solutions from electroplating operations, where cyanides are used in the process...", respectively. Subsequently the sediments in the lagoon became a listed hazardous waste under the same waste codes, under 40 CFR 261.3(b). Due to changes in regulatory status, the U.S. EPA and the Indiana Department of Environmental Management ordered the surface impoundment to be removed from service and closed.

In April of 1992 the Indiana Department of Environmental Management approved the surface impoundment Closure Plan, which called for: the installation of a soil/bentonite slurry cutoff wall around the entire impoundment and keyed into the underlying fine-grained glacial till layer; in-situ solidification of the lagoon sediments by mixing with cement/fly-ash grout; installation of a groundwater extraction system to create and maintain an inward hydraulic gradient; the construction of a RCRA composite cap over the entire impoundment; and appropriate monitoring controls.

Geologic Setting

The surface impoundment unit lies in a glacial outwash deposit of sand and gravel extending approximately 115 feet deep. The uppermost bedrock is the New Albany Shale. In the vicinity of the impoundment the glacial outwash is divided into an upper and lower unit by a relatively continuous fine grain deposit of glacial till at a depth of approximately 55 feet. This till contains a significant portion of silt and clay. Grain size testing on the till indicated that silt quantities ranged from 19 to 43%, clay from 20 to 25%, sands from 36 to 47%, and gravels from 4 to 7%, by weight. Plastic limits of the fine grained materials ranged from 8 to 10% while liquid limits ranged from 14 to 22%. This material is classified as CL and CL-ML under the Unified Soil Classification System. The vertical hydraulic conductivity of the till deposit ranged from 6 x 10^{-7} to 2 x 10^{-4} cm/sec.

The glacial outwash deposits are part of a continuous, unconfined aquifer which is tapped by production wells located at the plant and at some surrounding industries. The general groundwater flow direction in the aquifer is southerly, however pumping by the plant and surrounding industries has created a local groundwater depression. Published literature estimates of the hydraulic conductivity of the outwash sands and gravels to be about 40 to 415 feet/day (i.e. 0.014 to 0.15 cm/sec)[3].

Lagoon Sediment Characteristics

During the development of the Closure Plan, analytical testing was completed on the lagoon sediments to evaluate the chemical constituents and treatability. This testing indicated that while hazardous constituents from the wastewater sludge were present in the lagoon sediments, they did not leach from the sediments at an appreciable rate, nor were they detected in the groundwater monitoring wells adjacent to the lagoon. This allowed for the disposal of water removed from the sediments at the plant's existing wastewater treatment plant.

Due to the extremely soft nature of the saturated lagoon sediments, the collection of deep undisturbed samples was difficult. The crust that had formed on the higher areas of sediment after the surface water had been pumped off, was only approximately 6 inches thick and was not sufficiently stiff to safely support a mechanical drill rig. Therefore, the sediment sampling and analysis program was completed in two phases. Phase I involved the collection of shallow (up to 15 feet) samples by manual means, working off the top of the crust and around the edges of the lagoon. Phase II included sampling and testing throughout the entire depth of sediments using a drill rig, working from on top of the initial sand drainage layer placed over the sediments.

Classification testing on the lagoon sediments included moisture content, dry density, liquid and plastic limits particle size analysis, void ratio, and specific gravity. The moisture content testing indicated values as high as 200% for sediments less than 7 feet deep, and decreasing levels with depth to approximately 80% at a depth of 30 feet. Figure 2 contains the results of the dry density testing relative to the depth of the sample. Figure 2 illustrates that the shallowest sediments (directly below the desiccated crust) were at a dry density less than 30 pounds per cubic foot (pcf), and the density increased gradually with depth, to a maximum of approximately 50 pcf at a depth of 30 feet.

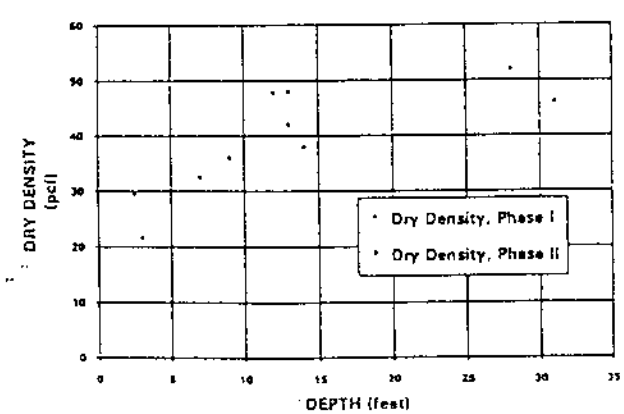

Figure 2 Sediment dry density variation with depth.

The average liquid and plastic limits of sediment samples that displayed plastic behavior were 57% and 42% respectively. All but two samples tested for particle size distribution had 99% or more passing the #200 sieve. Two samples had 60% and 89% passing the #200 sieve. The sediment void ratio ranged from 1 to 4, with an average of approximately 2.5. A general decrease in void ratio with depth was apparent although there was a large distribution in the results. The specific gravity of sediments varied widely from 1.3 to 2.6. This is indicative of the wide range of sources of the sediments, including lime from the wastewater treatment to fly ash, and cinders from boiler blow down water.

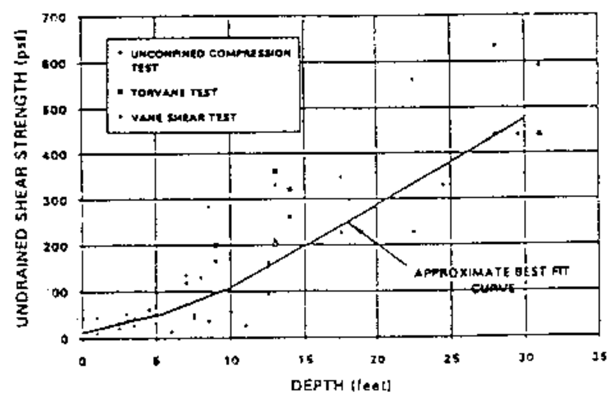

Figure 3 Sediment undrained shear strength versus depth.

Sediment shear strength testing included torvane and unconfined compression testing on undisturbed samples, and in-situ vane shear testing. The unconfined compression testing was completed in Phase II, after the placement of the initial sand lift. Figure 3 presents sediment shear strength data versus depth. An increase in shear strength with depth is apparent, although again the data is widely distributed.

One-dimensional consolidation tests were completed on four sediment samples. Two tests were run on samples during Phase I (HB-7 and HB-

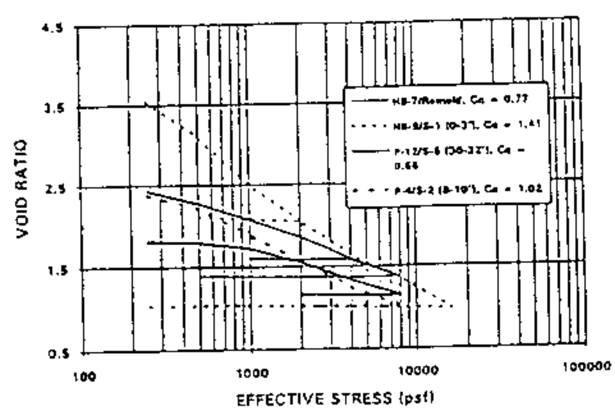

Figure 4 Sediment e versus log P, Consolidation curves.

9), and two tests were run on samples collected in Phase II (P-12 and P-4). The void ratio (e) versus log of the effective stress (log p) curves from these tests are shown on Figure 4. The compression index values for the sediments tested, ranged from 0.66 to 1.41. The deeper samples from a depth of 8 to 10 feet and 30 to 32 feet, displayed a prec nsolidation pressure of approximately 300 and 900 pounds per square foot, respectively, indicating that the sediments were generally normally consolidated under the stress of the saturated sediments themselves.

The coefficient of consolidation (Cv) values for each test and stress level are shown on Figure 5. The curves illustrate a general decrease in Cv with increasing stress level. The test run on the sample from a depth of 30 to 32 feet had slightly higher Cv values than the other tests. The Coefficient of Secondary Consolidation values from the consolidation testing, ranged from 0.001 to 0.04, with the lower value also coming from the deepest sample.

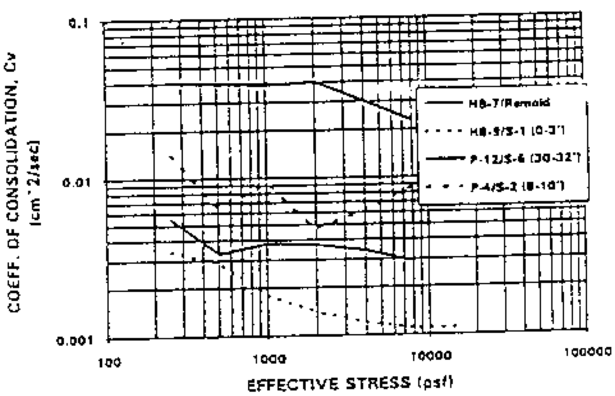

Figure 5 Sediment coefficient of consolidation versus stress level.

Solidification Feasibility and Cost

The Closure Plan originally called for in-situ solidification of the sediments by mixing with cement fly-ash grout. Mixing was to be accomplished using a modified caisson drilling rig, where grout is pumped through a hollow kelly bar and exits via ejection ports on the trailing edges of mixing blades.

In-situ solidification was originally chosen as the most practical means of stabilizing the sediments, to allow for the construction and support of the cap, due to the high sediment moisture content and low densities observed during the development of the Closure Plan.

The direct costs of the in-situ solidification were estimated at $56/cyd, based on an estimated sediment volume of 80,000 cyds. Therefore, the in-situ solidification of the sediments was estimated to cost $4,5000,000.

Consolidation Feasibility and Cost

During development of the Closure Plan, chemical testing was performed on the sediments and leachate, but little geotechnical testing was performed on the sediments. Therefore, the preliminary testing program (Phase I) was conducted to evaluate the physical properties of the sediments to assess the feasibility of consolidation. This program indicated that although the sediments exhibited very low shear strengths (i.e., less than 40 psf near the surface) at their existing moisture content, the material would gain strengths to about 100 psf or more, once the moisture content reached approximately 100%. Additionally, the one dimensional consolidation tests indicated that upon loading, the sediments would consolidate at a reasonable rate and appeared to have consolidation characteristics similar to naturally occurring fine-grained sediments (i.e. silt and clay).

Based on the promising results of the preliminary sediment testing, the possibility of using consolidation appeared feasible for support of the cap, provided that the economics could justify abandoning in-situ solidification. Subsequent cost estimations indicated the total price for surcharge loading, including mobilization charges, would be on the order of $29/cyd of sediment or about $2,300,000. This represented a potential cost savings of approximately 55% over in-situ solidification. Therefore, consolidation of the sediments was an attractive alternative.

The primary remaining concern was the constructability of the initial fill layer over the soft sediments. To limit the amount of sediment displacement and movement during fill placement, a biaxial geogrid was specified to be placed directly over the sediment. Also, dewatering of the sediments was initiated shortly after completion of the slurry wall, in an attempt to initiate the consolidation of the sediments and increase the in-situ sediment shear strength. The dewatering was conducted using a large diameter steel sump, lowered into the sediments. The dewatering caused a noticeable amount of consolidation to occur, and a "rapid drawdown" type failure in the higher sediments, which had the beneficial effect of flattening the sediment surface. These observations provided further evidence that consolidation of the sediments was a viable alternative.

Consolidation Design Considerations

The evaluation of the feasibility and cost for the construction of the preload necessary for the consolidation of the lagoon sediments required analysis of the consolidation and stability behaviors of the sediment/fill system. The following sections present a discussion of the analyses performed.

Predictions of Settlement

An initial goal of the preliminary sampling and testing program was to develop data necessary for the estimation of the amount of sediment settlement which could be expected. In order to model the sediment behavior, one-dimensional consolidation tests were performed on undisturbed and remolded samples. A remolded sample was evaluated because it was expected that the near surface sediments would become highly disturbed during the initial fill layer placement.

The consolidation tests and the sediment thicknesses provided the data necessary for an estimation of fill settlement. Expected settlements were evaluated for a series of sediment thickness/groups (i.e. 0-5 feet, 5-15 feet, 15-25 feet, and 25-35 feet). These were represented by an average sediment thickness in each group (i.e. 5 feet, 10 feet, 20 feet, and 30 feet, respectively). An average top of final cap elevation was assumed for calculation of the final overburden stress, and a conservative Compression Index (i.e. 1.41) was used to evaluate settlement. The expected primary consolidation settlements were then estimated using Terzaghi one-dimensional consolidation theory[2]. Figure 6 illustrates the expected settlement for each sediment thickness/group. The anticipated required fill volumes were estimated using the respective thickness/group surface areas and the corresponding predicted settlements.

Secondary settlement was estimated using the more conservative parameters determined during testing. For the 25 to 35 foot sediment thickness group, 0.8 feet of secondary settlement was estimated to occur after 50 years. Even though the composite cap would be capable of sustaining some differential settlement, it was decided to design the surcharge to remove as much of the anticipated secondary settlement expected to occur in 50 years as possible, during the anticipated 6 month period the surcharge would be in place.

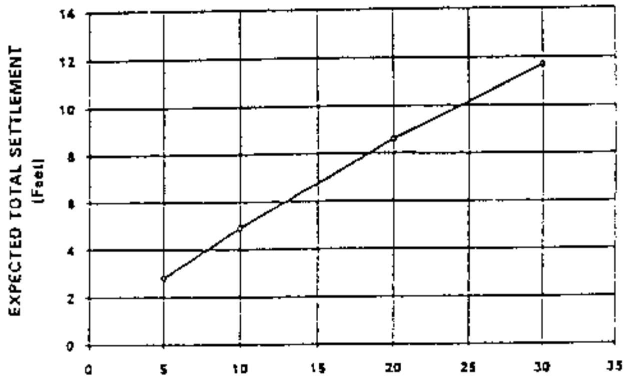

Figure 6 Estimated sediment settlement versus sediment thickness.

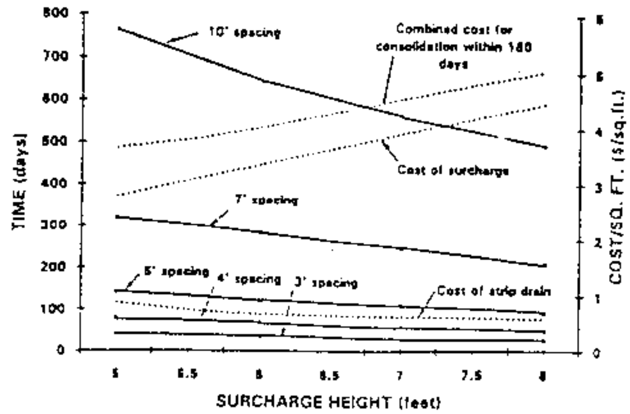

Figure 7 Time required for complete primary consolidation versus surcharge height, for various strip drain spacings, and cost curves for combinations of strip drain spacings and surcharge heights for consolidation within 180 days.

Accelerating Consolidation

To evaluate the feasibility of consolidation of the lagoon sediments, it was also necessary to estimate the time required to complete primary consolidation. As reported earlier the coefficient of consolidation, Cv, of the sediment ranged from 0.001 to 0.04 cm^2/sec. Since the testing indicated the average was closer to the lower end, Cv was taken to be 0.002 cm^2/sec or approximately 0.2 ft^2/day. The pore water drainage path was assumed to be vertical only from the top surface, because static groundwater levels in the lagoon had been observed to be several feet higher than the surrounding unconfined aquifer. Also, the initial excess pore pressure distribution was assumed to be constant with depth. Using Terzaghi's consolidation theory, and a percent consolidation required (Ureq%) of 98%, Tv=1.8, the time required for consolidation at a sediment thickness of 20 feet was estimated to be 10 years. This was obviously an overly conservative estimate, but it demonstrated that acceleration would be required to complete primary consolidation within a reasonable period of time, such as 6 months.

To accelerate the primary consolidation of the sediments, a combination of vertical strip drains and additional surcharge was proposed. An analysis was then undertaken to evaluate the required vertical drain spacing and surcharge loads at various sediment thicknesses. For the purpose of analyzing consolidation by radial drainage, Cvr, was taken to be the same as Cv. Then, using time factors for radial drainage, Tr [1], the time required for primary consolidation was determined. The contribution to consolidation from vertical drainage out of the top of the sediments was also evaluated, but found to have a small effect on rate, for strip drain spacings less than 6 to 7 feet and primarily only during the early portion of consolidation. Vertical drainage was therefore ignored in the analysis. The results of this analysis for a sediment thickness of 20 feet are graphically displayed in Figure 7. This figure shows the amount of time required for complet_ primary consolidation on the left axis, for various strip drain spacings and surcharge height combinations. On the right axis the cost per square foot of surface is shown for the combinations of surcharge heights and strip drain spaci; gs which will complete primary consolidation in 180 days. The total combined cost is also shown.

It is apparent from Figure 7 that vertical strip drains are much more efficient and cost effective, at accelerating consolidation than is additional surcharge. The actual optimum cost would be at a surcharge height less than is shown on the graph, but a minimum of 5 feet of surcharge was required for sufficient effective stress for removal of significant secondary consolidation. Therefore, at a 20 foot sediment thickness, a combination of 5 feet of surcharge and a strip drain spacing of approximately 5.5 feet was called for. The total cost of this combination was approximately $3.70 per square foot.

Preload Stability

One of the initial questions regarding the use of a surcharge to consolidate the lagoon sediments was whether or not the fill could be placed over the very soft material. After removing the surface water from the lagoon, an investigation of the near surface sediments revealed that a thin desiccated crust (6 to 12 inches) had formed over the higher portions. Beneath this crust and in lower areas, the surficial sediments had little to no shear strength. Deeper probing revealed that the shear strength did increase with depth, but the sediments were too soft to allow for access of heavier equipment necessary for the collection of deeper undisturbed samples.

A preliminary stability analysis was undertaken to evaluate the feasibility of placing the fill, based only on the limited initial data. The sediment strength parameters used in this analysis were a cohesion, c, of 20 psf at the surface and linearly increasing by 1 psf per foot of depth. The shear strength friction angle was conservatively assumed to be zero because of a lack of adequate data and uncertainty regarding pore pressure distribution and dissipation with loading. Stability analyses were then completed using "PCSTABL5" and the Modified Janube Method. Analysis of a three foot sand fill layer placed directly over the sediments indicated a factor of safety less than 1. Therefore, a biaxial geogrid was proposed to help distribute the fill load and "bridge" softer areas of sediment. A discussion of the difficulties placing the initial fill layer will be presented in the next section.

Additional analysis indicated that shallower lifts placed over the initial 3 foot lift had factors of safety greater than one. Also, as previously reported, vane shear testing indicated that the sediments developed higher shear strengths with depth. This was primarily the result of what was a significant increase in effective stress, from just the first lift of fill, over the normally consolidated, saturated, sediments.

Preload Construction

Construction operations for the consolidation of sediments, began in May 1993, with the installation of Tensar BX-1200™ geogrid and the placement of a sand drainage layer (approximately 3 feet in thickness). Manufacturers specifications called for the geogrid to be installed in a shingle like manner, with 3 to 5 foot seam overlap. Seams were to be mechanically fastened on 5 foot centers using plastic zip strip ties. The geogrid was to be anchored around the perimeter of the lagoon in a 10 foot wide bench, cut to the elevation of the sediment surface.

Drainage layer fill was to be placed using a low contact pressure bull dozer, approximately equivalent to a Caterpillar D-4 dozer in gross weight. The fill sequence was such that the dozers were to cover the lapped seams first with about 2 to 3 feet of sand drainage material, then cover the center of the sheets. The dozers were to move fill to the leading edge in a gradual manner, such that a large mound of fill would not be advanced across previously placed fill and only a thin leading edge would be advanced over the sediments.

Several days into this operation it became apparent that the near surface sediments were too weak in certain areas of the lagoon to support this approach. The advancing fill tended to push down the sediments near the leading edge, forming a "mud wave". Additionally, as the leading edge advanced, the height of the wave tended to increase, making it more difficult to control.

A number of alternative placement techniques were attempted in and effort to control the "mud wave" problem. These included reducing the initial layer thickness, using lighter equipment, and installing a series of "stab" wells and pumping to dewater the sediments. While these methods proved effective in many of the lagoon areas, the "mud wave" problem was not completely eliminated. An effective placement method was developed utilizing a track mounted backhoe to place fill in small piles, ahead of the leading edge, allowing it to sit overnight, then typically the dozers were able to directly access the area and level out the fill the following morning.

While this method was the most successful in the difficult areas, it proved to be much slower than anticipated. The drainage layer placement took 67 workdays to complete when it was anticipated to take only 45. Additionally, while covering the sediments, occasional localized stability failures occurred. During these failures the underlying geogrid tore and a large area of fill would drop by 2 to 5 feet. Also, the most fluid sediments would be forced up through cracks in the fill and flow over the leading edge of fill. Typically, once these failures occurred, stresses were relieved the area would stabilize.

Wick drain installation was commenced once a sufficient area of the lagoon was covered with the sand drainage layer. Amerdrain™ wick drains were installed using a 15 ton mandrel attached to a Komatsu 300 backhoe. Drain spacing in the shallow areas (i.e., less than 20 feet of sediment) was on a 5 foot rectangular grid. In areas where sediments were thicker, a 5 foot triangular spacing was used to reduce the drainage path length slightly.

In the Closure Plan the average sediment thickness was estimated to be 10.6 feet. Based on this thickness it was estimated that approximately 100,000 feet of wick drain would be required, provided a 5 foot rectangular spacing was used and drains were not installed in areas where the sediment thickness was less than 5 feet. During the drain installation, it became apparent that the depth of sediment had been underestimated. Sediment thickness averaged 16.2 feet indicating that the sediment volume had been underestimated by 52%. Consequently, a total of 197,000 feet of wick drains were installed in the lagoon sediments.

Shortly after wick drains were installed in an area of sediment, a dramatic drop in pore pressures was observed and a corresponding increase in stability was apparent. This drop in pore pressure can be seen on Figure 8, where elevation heads decreased by 5 to 8 feet after 30 days, during placement of additional fill. This response was typical at all the piezometer locations, following installation of the drainage wicks.

Prior to completing wick drain installation, a gravity drainage system was installed in the initial drainage layer to remove water which would become trapped when the general fill was placed. The system consisted of 2 sumps constructed of galvanized steel with finger drains extending radially out in four directions. The sumps were situated in the areas of the lagoon expected to experience the most settlement. The sumps were equipped with submersible pumps that fed into the plants wastewater treatment system.

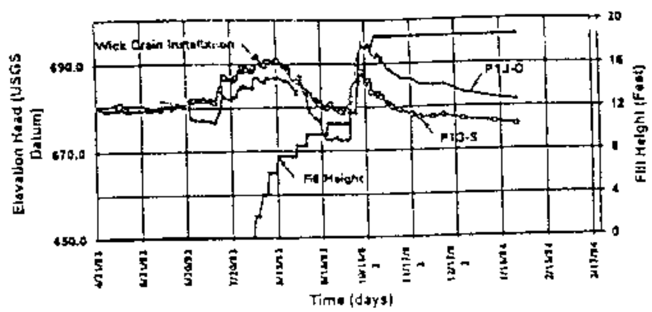

Figure 8 Time dependant pore pressure data from piezometer cluster P-13 (S-shallow and D-deep).

Once the gravity drainage system was installed, placement of the general fill commenced. The first lift was placed using a Caterpillar D-4 wide-tracked dozer. Subsequent lifts were placed using heavier equipment including Caterpillar D-8 dozers, 977 loaders, and rubber tired scrapers, with no stability problems.

Instrumentation and Monitoring

Field monitoring was considered to be critical for the safe and successful completion of the installation of the fill. A series of pneumatic piezometers and settlement monuments were installed in order to monitor the behavior of the sediments. In deeper areas of sediment, clusters of three piezometers were installed at the top, middle and bottom. Data from this instrumentation was plotted on a daily basis. Figure 8 presents the pore pressure data from one piezometer cluster, designated P-13.

Settlement monuments were installed on top of the initial drainage layer, after the wick drain installation was complete. Figure 9 presents the data for settlement monument SM-6 (the field settlement curve was adjusted by 2 feet, which was the amount of settlement estimated to have occurred prior to the installation of the settlement monument). The curve shows a rapid increase in settlement immediately following installation of the wick drains. On the plot is also a curve for the theoretical settlement which would have occurred since the fill had first been placed at that location assuming radial drainage.

Conclusions

The project presented many interesting geotechnical challenges, some of which were easily addressed and others created significant problems. The limited laboratory testing program proved to be adequate for a reasonable estimation of the consolidation behavior of the lagoon sediments. The greatest difficulty and obstacle in completing the project, was the construction of the initial drainage layer over the very soft lagoon sediments. The early dewatering of the sediments proved to be invaluable in allowing for the subsequent placement of fill. The biaxial geogrid was critical in allowing the

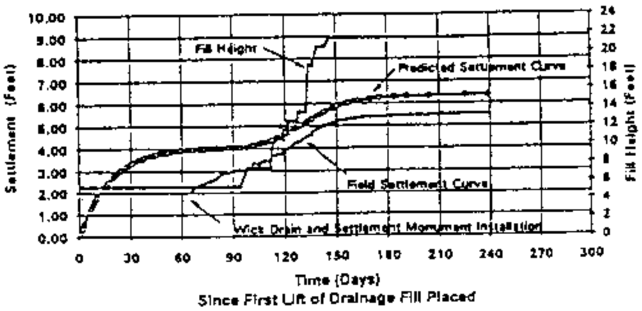

Figure 9 Time dependant settlement at monument SM-6, theoretical and settlement assuming radial drainage, and height of fill at SM-6.

placement of the initial sand layer, which could not have been done without some form of reinforcement. Evaluation of stability accurately predicted the stability of the sediment/fill system, which made it obvious at an early stage that reinforcement would be necessary. Also, the stability after the initial sand layer was placed was accurately predicted, as ease of later construction demonstrated.

The utilization of wick drains for the acceleration of consolidation proved to be cost effective and successful. Wick drain installation also had a dramatic effect in increasing the stability of the sediments.

This project demonstrated that deep, very soft, saturated, normally consolidated, wastewater lagoon sediments, can be preloaded and consolidated for the subsequent support of a cap. This construction method gives engineers and owners a cost effective alternative for the closure of a wastewater lagoon.

Acknowledgments

The authors would like to extend special thanks to: Eric Mendel, client's representative; Martin Battistoni and Thomas Uher, Rust Remedial Services, Inc.; Steve Schleede, Jim Berry, Steve Euker and Jim Thomson, Schleede Hampton Associates; John Cole, John Cole Contracting; and Bill West, GZA GeoEnvironmental, for their assistance and cooperation during this project.

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